

# CLOUD FRACTION: CAN IT BE DEFINED AND MEASURED?



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## MOTIVATION

- Clouds are the most uncertain component of GCMs.
- Climate sensitivity in GCMs depends strongly on the representation of clouds.
- GCMs must be evaluated on the basis of their representation of clouds.
- Cloud fraction is the zeroth order measure of clouds in models and observations.

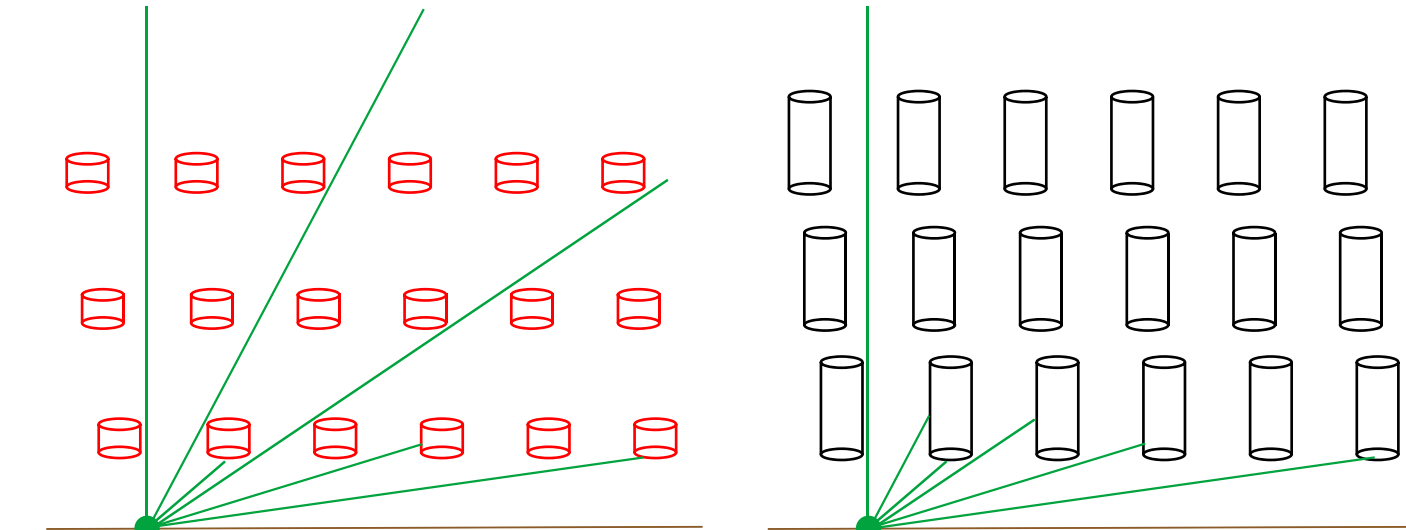
Surprisingly, and in spite of the fact that we deal with clouds on a daily basis, to date there is no universal definition of a cloud. . . . Ultimately, the definition of a cloud depends on the threshold sensitivity of the instruments used in cloud studies.

*Clothiaux, Barker & Korolev (2005)*

## SOME CAUSES

### CLOUD SIDEWALL EFFECT

Both cloud fields have same cloud area fraction



Vertical view angle yields same cloud fraction.

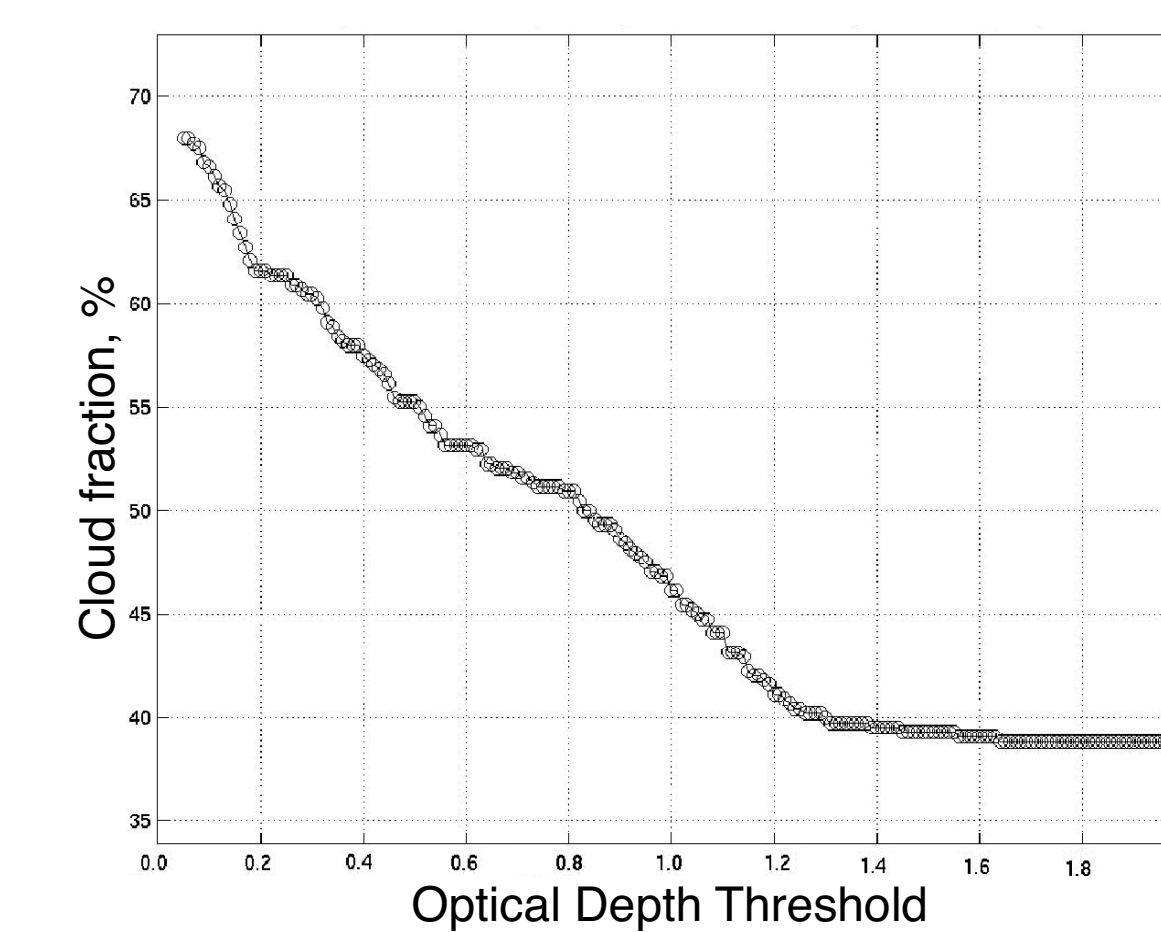
Slant view angle yields artifact high cloud fraction because of cloud sidewalls, more so for tall clouds.

Pertains to cloud fraction from satellite and from surface.

The effect can be minimized by restricting viewing zenith angle.

## THRESHOLD

### CLOUD FRACTION DEPENDS ON OPTICAL DEPTH THRESHOLD



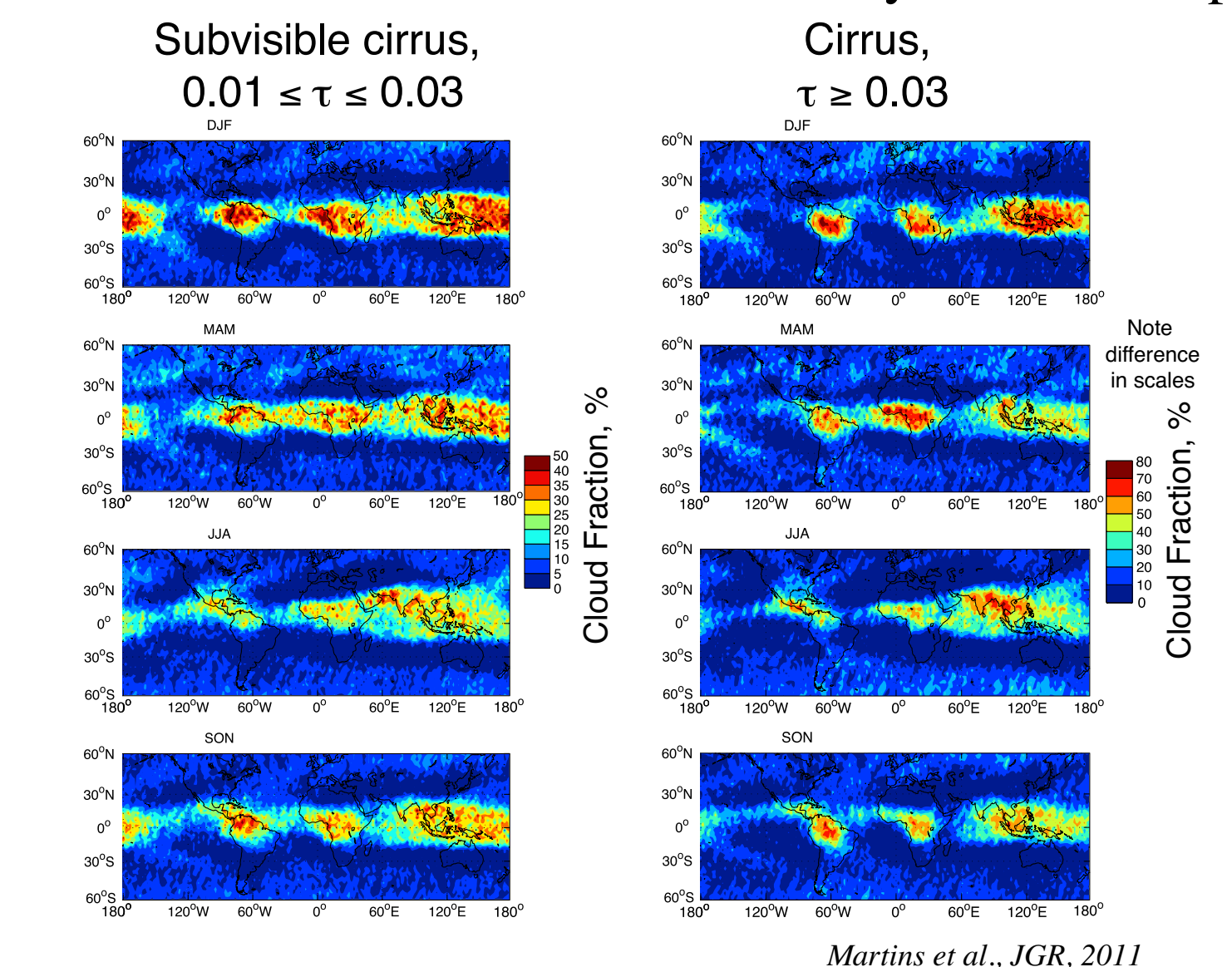
*Mores (MS Thesis, Univ Wisc., 2004, Eloranta)*

Fraction of time cloud detected by lidar as function of optical depth threshold during a single night of observations. Cloud fraction increases strongly with decreasing threshold.

## IMPORTANCE

### OPTICALLY THIN CLOUDS CAN BE PREVALENT, ESPECIALLY IN TROPICS

Subvisible cirrus and cirrus detected by lidar from space

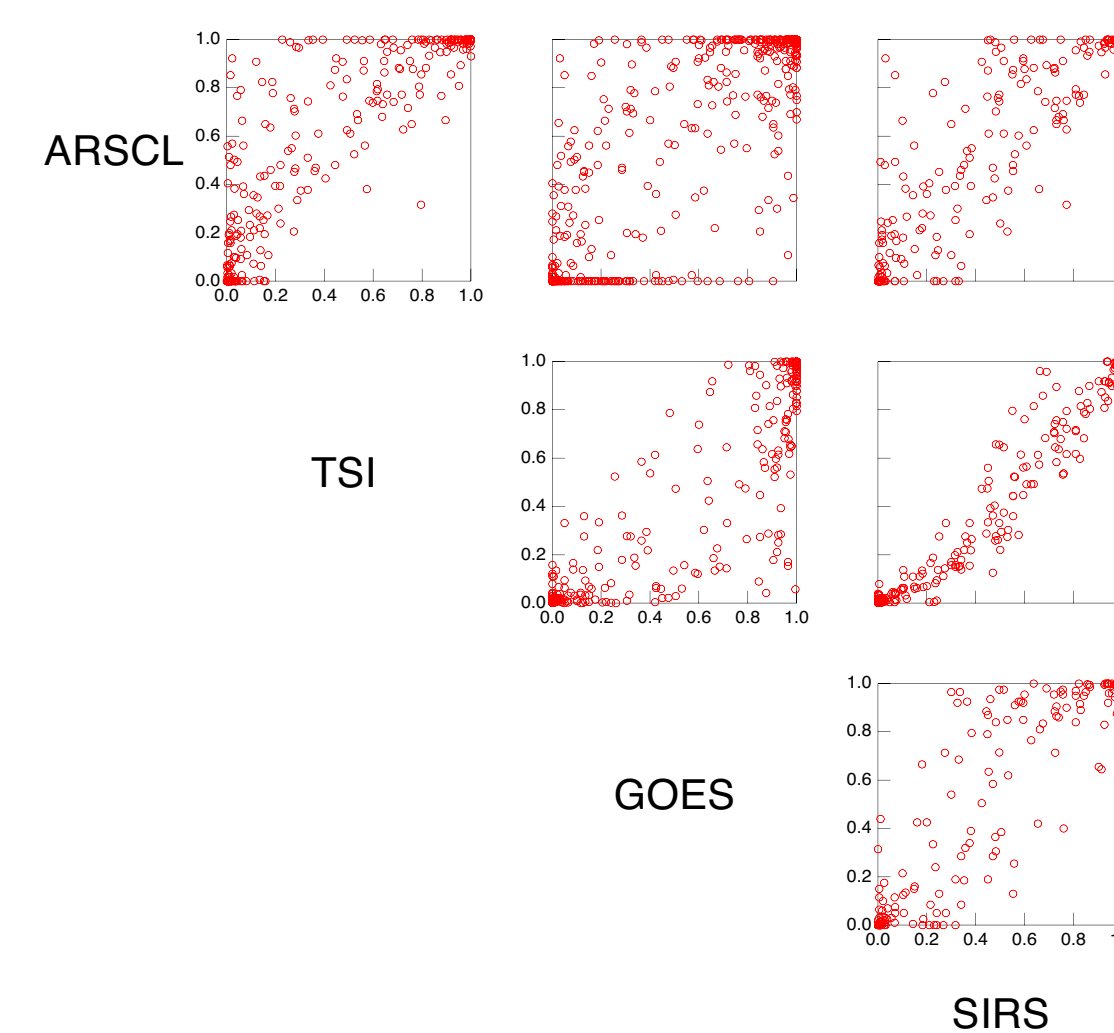
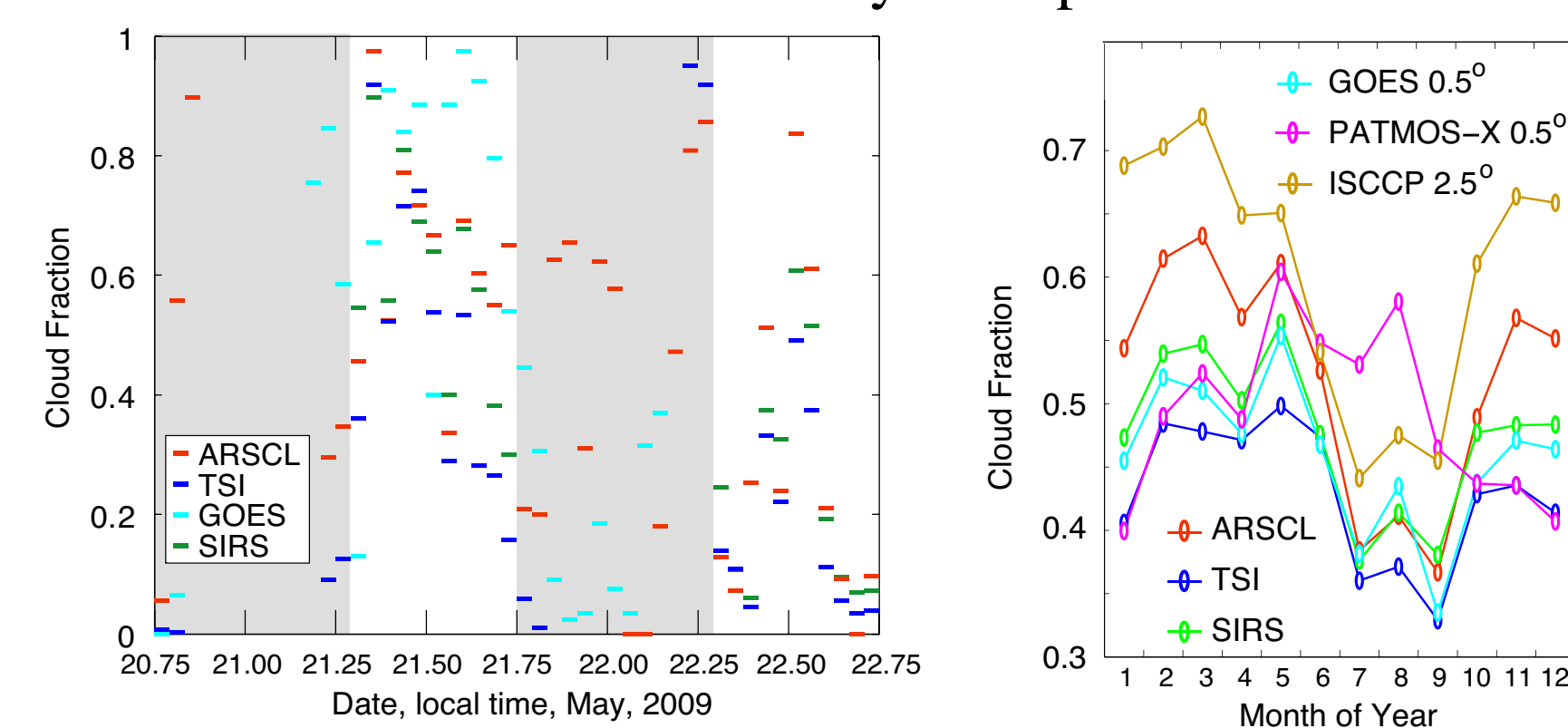


*Martins et al., JGR, 2011*

## THE CHALLENGE

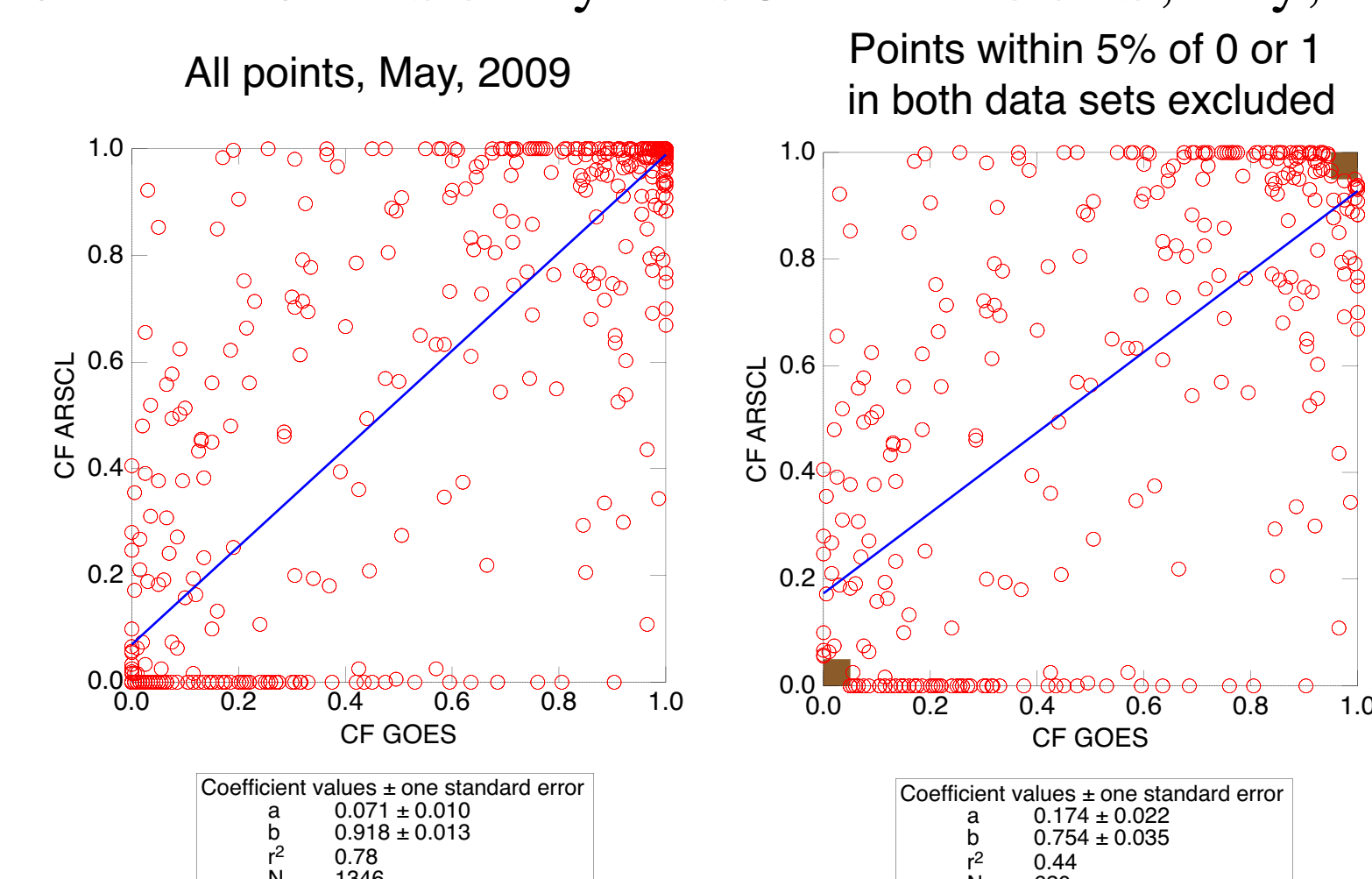
### DIFFERENT MEASURES YIELD DIFFERENT CLOUD FRACTION

Cloud fraction at SGP by multiple methods

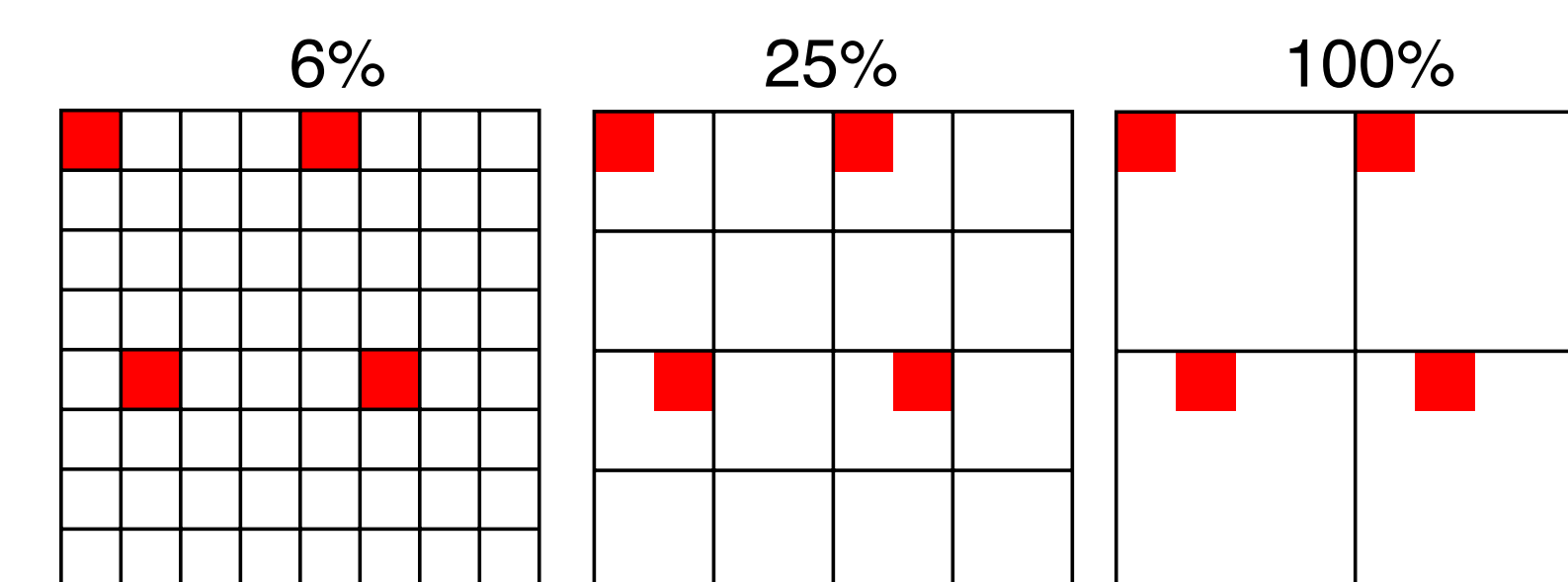


### CORRELATION IS DOMINATED BY ONES AND ZEROES

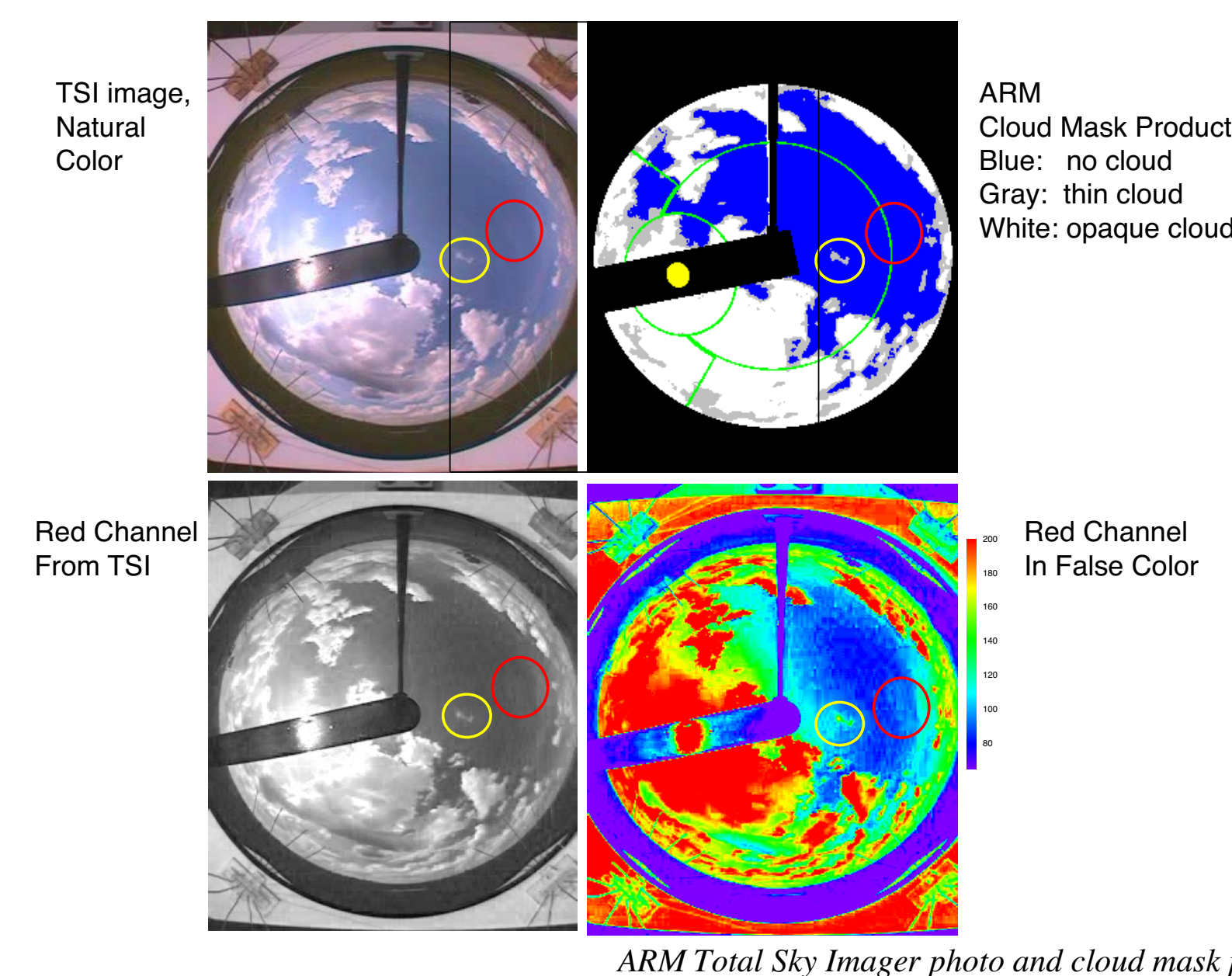
Cloud fraction at SGP by ARSCL AND GOES, May, 2009



### CLOUD FRACTION DEPENDS ON RESOLUTION

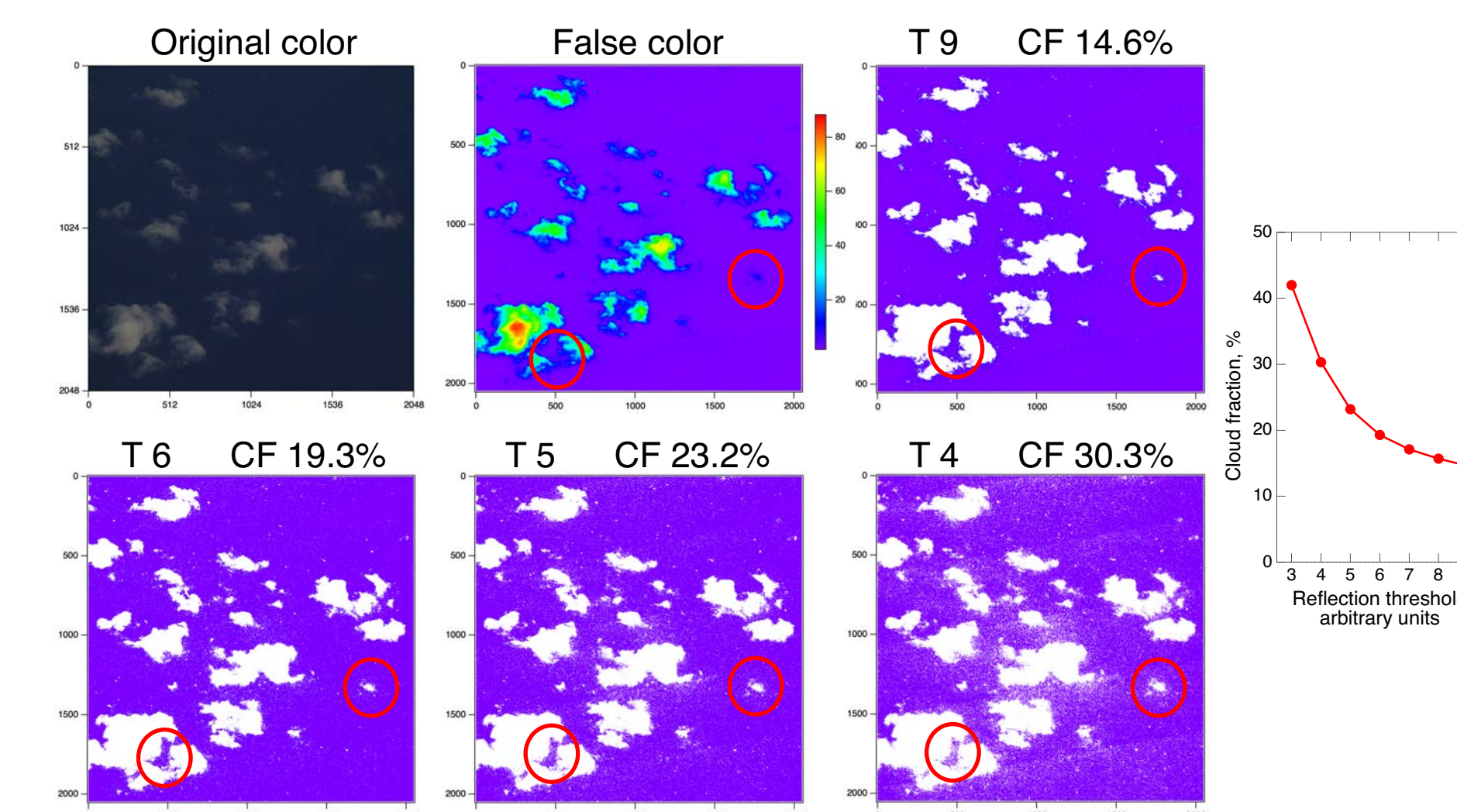


### CLOUD DISCRIMINATION ALGORITHMS CAN MISS THIN CLOUDS



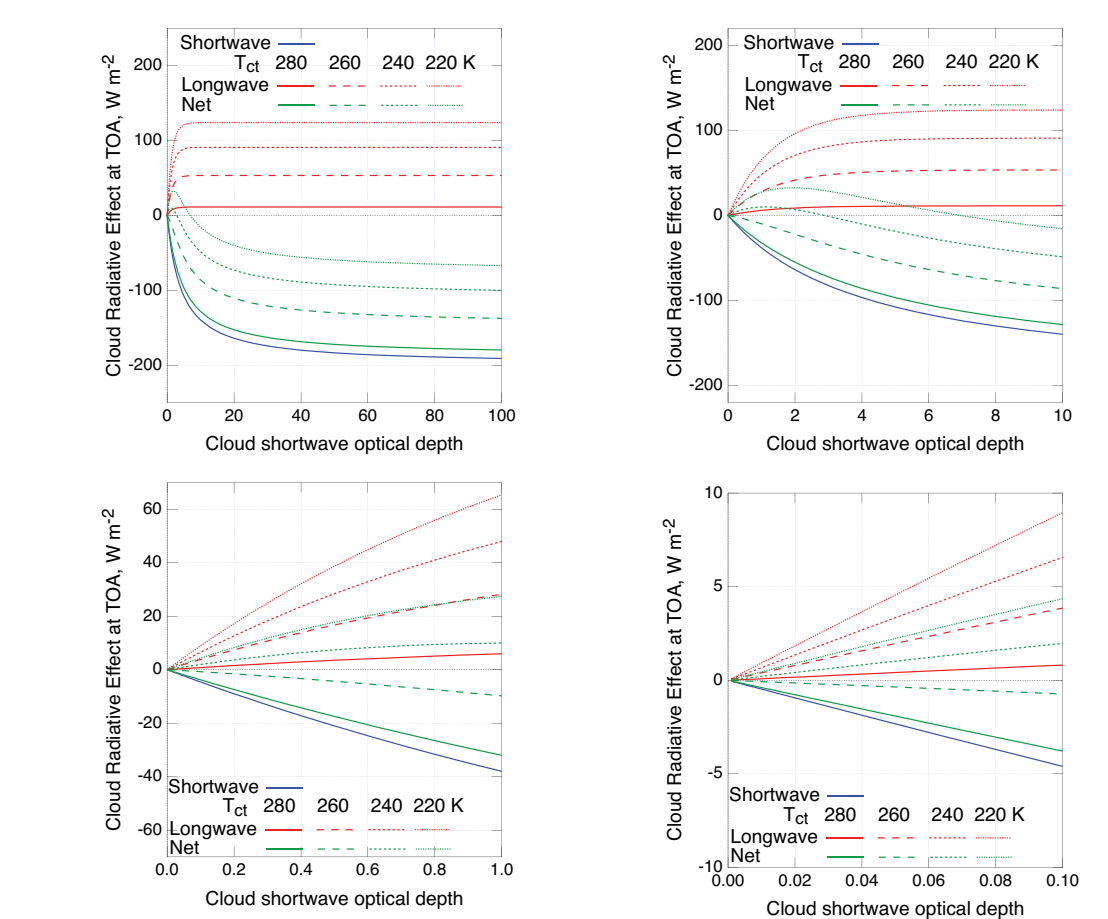
*ARM Total Sky Imager photo and cloud mask product*

### CLOUD FRACTION DEPENDENCE ON THRESHOLD



Low reflectance cloud edges contribute substantially to cloud fraction. Difficult to find threshold that avoids false positives and false negatives.

### CLOUD RADIATIVE EFFECT – DEPENDENCE ON OPTICAL DEPTH AND CLOUD-TOP HEIGHT



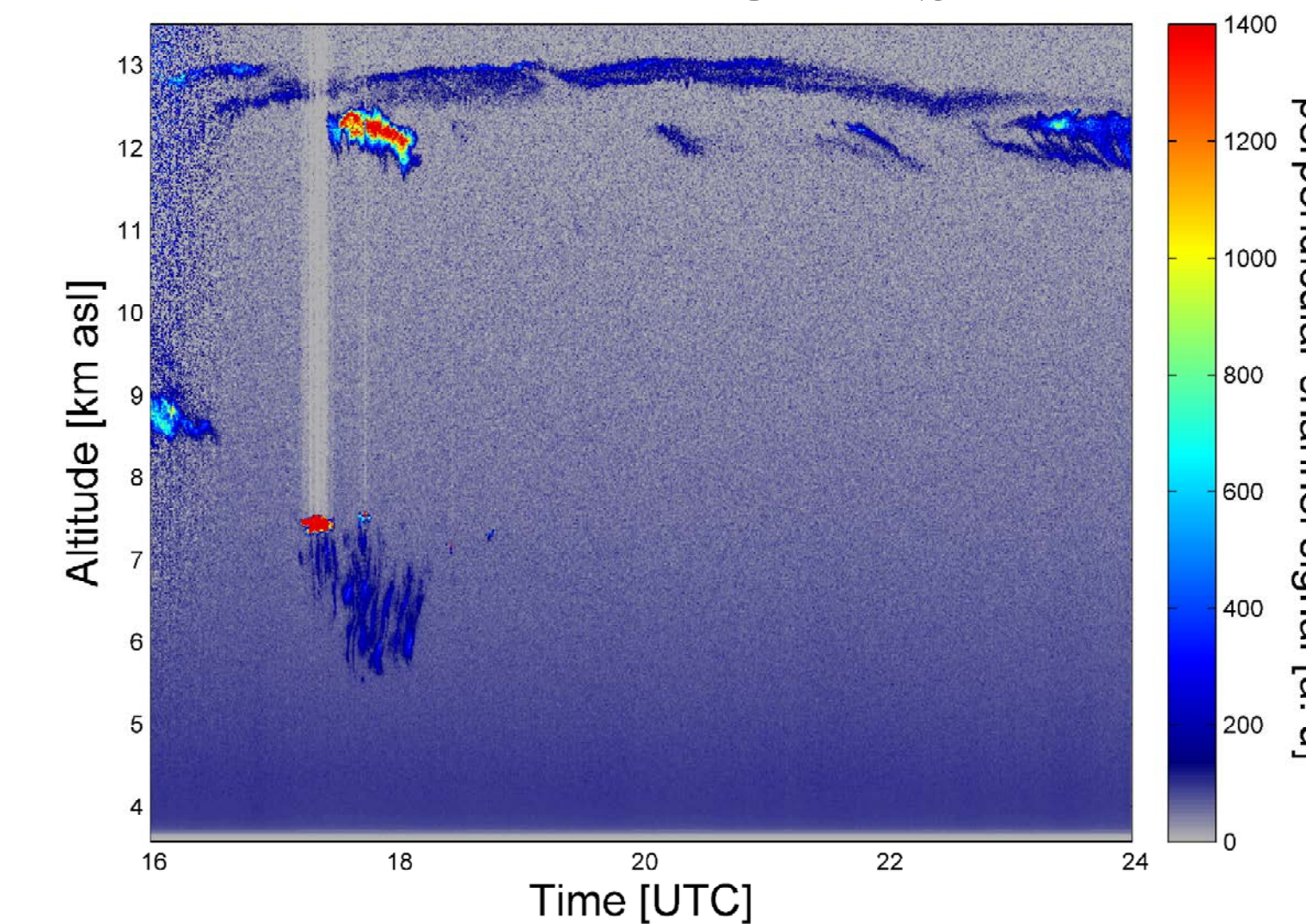
Shortwave TOA CRE is 24-hour average at equinox for latitude of ARM SGP site. Surface temperature, 285K; surface albedo, 0.15.

Even for thin cirrus clouds,  $\tau_{sw} \sim 0.01$ , the radiative effects are substantial,  $-0.5 \text{ W m}^{-2}$  in the shortwave and as great as  $1.8 \text{ W m}^{-2}$  in the longwave.

## IMPLICATIONS

- Cloud fraction inherently depends on measurement technique.
- Cloud fraction alone is not enough.
- Cloud fraction is inherently binary.
- Evaluation of model representation of clouds needs to focus on continuous cloud properties such as liquid water path.

### PERSISTENT VERY THIN CIRRUS AT MIDLATITUDE SITE



*Kienast-Sjögren et al., 9<sup>th</sup> Int. Symp. on Tropospheric Profiling, 2012*

Optical depth of cirrus layer estimated as 0.003 to 0.004.